DOCUMENT RESUME

ED 373 976 SE 054 622

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TITLE	Patterns of Attainment in Standard Grade Mathematics 3-6. Interchange No. 21.
INSTITUTION	Scottish Council for Research in Education.
REPORT NO	ISSN-0969-613X
PUB DATE	94
NOTE	13p.; For the full report, see SE 054 373.
AVAILABLE FROM	Dissemination Officer, Scottish Council for Research in Education, 15 St. John St., Edinburgh EH8 8JR, Scotland, United Kingdom (7 British pounds).
PUB TYPE	Collected Works - Serials (022)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Foreign Countries; High Schools; *High School Students; Instructional Materials; *Low Achievement; *Mathematics Achievement; Mathematics Education; *Mathematics Tests; *Textbooks
IDENTIFIERS	Scotland

ABSTRACT

The interchange series of documents aims to improve the Research and Intelligence Unit's dissemination of the findings of research funded by the Scottish Office Education Department. In 1991 this department commissioned the Scottish Council for Research in Education to investigate the performance in Standard Grade mathematics of those candidates who were judged to be average to below average and to identify changes which might lead to improvements in the teaching of basic competencies in mathematics. This document reports the results of studying the classroom work and examination scripts of over 600 average and low-attaining secondary school candidates earning overall grades of 3 to 7 in two areas: (a) knowledge and understanding, and (b) reasoning and applications. A study of test scores indicates that performance in mathematics peaked at a grade of 5 and the criteria that were most important in differentiating between grade 4 and grade 5 performances were the abilities to handle symbols, generalize, and solve problems. Study of classroom work and teacher profiles of students, teaching materials, and support from teachers showed: (1) Teachers use a wide range of texts, not all of which are especially written for Standard Grade mathematics; (2) Teachers are often over-supportive of lower-attaining pupils; and (3) Lowest-attaining pupils are introduced to a very limited range of mathematics. Implications for teachers of low to average students are discussed. (MKR)

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THE SCOTTISH OFFICE
Education Department

INTERCHANGE

No 21

Patterns of Attainment in Standard Grade Mathematics 3–6

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ISSN 0969-613X

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Edited and produced for the Scottish Office Education Department by the SOED Dissemination Officer at the Scottish Council for Research in Education, January 1994.

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Patterns of Attainment in Standard Grade Mathematics 3–6

Marion Devine, Donald Gray and Harry Black

The Scottish Council for Research in Education

Standard Grade courses have been in place now for almost 10 years. The curriculum is firmly established in secondary schools and teachers are familiar with the criteria which are used both to plan and assess courses. One of the major changes introduced by Standard Grade was to extend assessment for certification purposes to virtually the entire ability range within the school, thus allowing those pupils who were previously categorised as 'non-certificate' to be given recognition for their achievements. In 1991 the Scottish Office Education Department commissioned the Scottish Council for Research in Education to investigate the performance in Standard Grade mathematics of those candidates who were judged to be 'average to below-average' and to identify changes which might seem desirable in grade-related criteria which might lead to improvements in the teaching of basic competences in mathematics.

The structure of Standard Grade mathematics

Standard Grade provides certification for pupils of virtually all abilities.

What can low attaining pupils do in mathematics?

Standard Grade mathematics consists of three assessable elements: 'Knowledge and understanding', 'Reasoning and applications' and 'Investigating'. Each element comprises a series of extended grade-related criteria (EGRC) which is written at three levels: foundation, general and credit level. Two elements, 'Knowledge and understanding' and 'Reasoning and applications', are assessed externally while 'Investigating' is assessed internally. This study was mainly concerned with the external assessments.

Three sets of examination papers are available to match the three levels. Most candidates attempt two consecutive papers, credit and general or general and foundation. Low attaining pupils may sit the foundation paper only. Awards are made on a six point scale from 1 or 2 (credit level) to 5 or 6 (foundation level). Pupils who complete the course but fail to attain grade 6 are classified as grade 7.

Although the EGRC are used to prepare the questions for the Standard Grade examination, they are not used directly to grade the

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papers. Marks are awarded for each question or part question and the total mark for each element is compared with upper and lower cut-off scores. These cut-off scores determine which grade is awarded within each level.

Sources of evidence

Two main sources of information — examination scripts and classroom work — provided the evidence for the study. Over 600 examination scripts from candidates gaining overall grades 3 to 7 were analysed in both 1991 and 1992. Six large schools selected from across Scotland were visited and the class work of a sample of low attaining pupils studied. The examination papers of those pupils were included in the 1992 sample scripts. The same framework was used to analyse examination scripts and classwork.

The framework for analysis

The researchers' analysis of pupils' work depended on directly grading their work according to predetermined criteria.

To what extent can teachers use a direct grading system to support teaching and learning in the classroom?

At the start of the project a working group of mathematics educators was set up to agree a framework which could be used to analyse both examination scripts and pupils' work in the classroom. Several options were considered, including possible derivations of the SOED *Mathematics 5–14* curriculum guidelines or the criteria used in the Assessment of Achievement Programme. On reflection, it was felt that since both the Scottish Examination Board (SEB) and teachers were familiar with the EGRC, it was preferable to retain the existing criteria at least as a basis for the framework.

Changes were made by sub-dividing some of the criteria and by adding others using the researchers' own codes. The increased detail allowed the researchers to explore possible differences in performance within an EGRC. A total of 38 'Knowledge and understanding' criteria and 24 'Reasoning and applications' criteria were studied.

How the framework was used

All the analyses which were carried out during the study made direct use of the framework. Every question in each examination paper was analysed in terms of the framework to determine which of the criteria were included. Every response was directly assessed with reference to the same criteria. Marks were not awarded — either the response met the criterion or it did not. Similarly, in the classroom, textbooks were analysed to check the opportunities offered to pupils and the pupils' written work was scrutinised for evidence of success. In addition, teachers were asked to prepare a profile of competences for each pupil based on the same framework.

Links with mathematics 5–14

Although it had been decided not to use the 5–14 strands and targets as a basis for the framework, the number of criteria being

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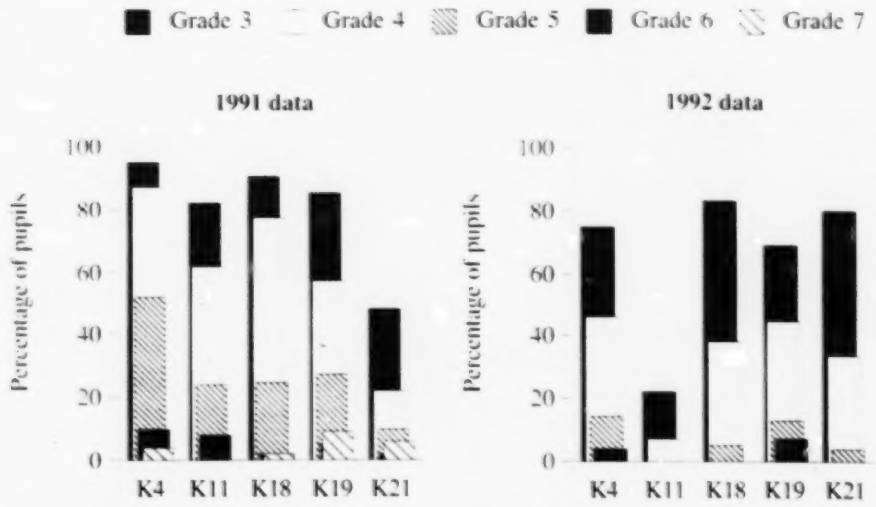
studied was too numerous to report on separately. Therefore, eight categories derived from the 5–14 programme were used to group and present the findings, five within 'Knowledge and understanding' — number, measuring shape, relationships, shape, information handling — and three within 'Reasoning and applications' — interpreting a task, doing a task, completing a task.

Examination performance

The focus of the research was on the average and lower attaining pupils — those working at general and foundation levels. For each group of criteria a profile was prepared showing the percentage of pupils successful in each criterion. The pupils were classified by their overall mathematics grade in the Standard Grade examination. In general the profiles of competence for each grade demonstrated constant patterns of attainment. A typical pattern is shown in the profiles relating to measuring shape (Figure 1).

Figure 1. Percentage of pupils successful at measuring shape (general level)

K4 Interpret scale drawings with scales as ratio or scaled line
K11 Construct scale drawings with scale not given
K18 Calculate the circumference of a circle
K19 Calculate the area of a triangle, kite, parallelogram, rhombus, composite figure
K21 Calculate volume of a cylinder, triangular prism



The pattern over both years was constant in that the number of pupils attaining success fell as the overall grade decreased from 3 to 7. Within each year the peaks and troughs for each group of pupils were similar. In 1991, K4 was attained by the largest number

of pupils within each grade and, with the exception of pupils attaining grade 7, K21 by the least. In 1992 the peaks and troughs were again similar although, in this case, K11 proved much more difficult for pupils at all grades and K21 was easier but only for the higher attaining pupils.

The full report of the research contains similar profiles for each of the criteria analysed and provides a commentary on the similarities and differences between performances over the two years.

Certain criteria were identified as differentiating highly between grade 4 and grade 5.

Are pupils on the borderline between foundation and general level given the opportunity to develop the competences listed in Table 1?

Differences between grade 4 and grade 5

Over the past few years, performance in the examinations for Standard Grade mathematics have peaked at grade 5. Therefore, in studying the profiles of competences for each criterion, particular attention was paid to the differences between grade 4 and grade 5 performances. Any information which teachers could use to help pupils overcome the hurdle between these grades might be valuable.

A total of 27 general level criteria were available in both the 1991 and 1992 papers. Table 1 shows the three criteria that were identified as differentiating most highly between grade 4 and grade 5.

Table 1. Criteria that were most important in differentiating between grade 4 and grade 5 performances

The ability to handle symbols
- Interpret scale drawings with scale as a ratio or representative fraction
- Calculate the circumference of a circle
- Solve simple equations
- Evaluate formulae in symbols
- Solve right-angled triangles using trigonometric ratios
- Create a simple relationship in symbols

The ability to generalise
- Explain solution in general terms
- Continue patterns
- Generalise features of a pattern

Early stages of problem solving
- Interpret information involving two/three straightforward sources
- Decide the steps (two/three only) and their order in non-routine problems

Work in the classroom

The second aim of the study involved a study of the work of low attaining pupils in the classroom. For this, the researchers worked in six large schools drawn from across five different regions. Discussions were held with teachers in each school to identify a group of 12 low attaining pupils in S4. One or two researchers spent a week in each school studying texts used, observing and talking to the pupils in the classroom and scrutinising their written

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work. Using the same framework as was used to analyse the examination papers, a profile of competence was prepared for each pupil.

The class teachers were also asked to complete a similar profile for each pupil and to indicate which criteria were introduced and developed as part of the course. Some classes were mixed foundation/general others were foundation only. There were differences between classes in the extent to which pupils were given the opportunity to develop general level skills and this was taken into consideration when establishing competence.

Teaching materials

Teachers use a wide range of mathematics texts in the classroom not all of which are especially written for Standard Grade mathematics.

How easy is it for teachers to analyse existing texts in terms of EGRC? Can this task be shared among teachers or carried out centrally?

All schools used a variety of textbooks with their classes and over the six schools a total of 20 different texts were used. A checklist of content is provided in *Standard Grade arrangements* 'to assist teachers in selecting material for courses at each level' and this makes it relatively easy to categorise the texts in terms of the skills needed to attain the EGRC of 'Knowledge and understanding'. The relationship between content and 'Reasoning and applications' is far less clear. It was difficult to identify within the texts, opportunities for pupils to develop and practise the skills identified in 'Reasoning and applications'. Authors of textbooks rarely, if ever, seemed to consider the possibility of including information (to teachers and pupils) which would identify the range of skills being introduced.

Support for pupils

At the time the school visits took place, the pupils were involved in revision work, practising past papers or completing investigations. There was no teaching of new material. The following comments are, therefore, limited in the extent to which they might apply to teaching at earlier stages of the course.

Teachers are often over-supportive of lower attaining pupils.

Are some teaching methodologies more successful with low attaining pupils than others? Can teachers be given guidance on how to withdraw support gradually?

The classes were small enough for the teacher to talk to each pupil individually, providing support as necessary. The distinction between support and 'spoon feeding' is a fine one. At least two of the teachers referred to this as a problem. They wanted to provide the maximum support and guidance while encouraging pupils as far as possible to develop their own thinking skills. Whereas supportive teaching involves asking probing questions and providing prompts towards a solution, spoon feeding simply supplies the solution or the method. Some pupils made no attempt to think for themselves and asked their peers or the teacher for help at every stage.

So what can pupils estimated to be grade 7 do in the classroom?

Those criteria which were attained by over 80% of pupils estimated to be grade 7 were identified as grade 7 competences. A total of 13 foundation level criteria came within this definition (Table 2).

Table 2. Criteria attained in classwork by pupils estimated to attain grade 7

Calculations in number and shape
- Calculate using four rules with whole numbers and decimals
- Calculate simple percentages of quantities
- Calculate the perimeter of a rectilinear figure
- Calculate area of rectangle, square, right angled triangle

Information handling
- Extract information from simple tables with two/three categories
- Interpret graphs with straightforward scales
- Interpret pie charts, identifying largest and smallest sectors
- Complete a table
- Complete graphs given the scale in words and the structure

Shape
- Plot coordinates in the first quadrant
- Recognise simple symmetrical figures with line symmetry

Starting a task
- Interpret a problem using two/three sources (statement and diagrams)

Doing a task
- Continue simple patterns

The only major category of mathematics that is completely missing from the above list is the category 'relationships'. Many pupils at the lower levels of attainment have access to a restricted range of knowledge and skills and few were given the opportunity to handle relationships.

Although no general level criteria were identified as grade 7 competences, four of the foundation level competences above, when extended to their general level equivalents, were attained by over 50% of pupils estimated as grade 7. These were:

- Calculate the circumference of a circle
- Calculate the area of a kite, parm, rhombus or circle
- Interpret pie charts using proportion of sectors
- Construct graphs when scale is not given.

The lowest attaining pupils are introduced to a very limited range of mathematics.

What are the advantages and disadvantages of widening the range of opportunities for these pupils? How helpful is the accompanying list in deciding where to start?

Teachers seeking to widen the range of opportunities offered to lower attaining pupils might start with the set of general level criteria above and extend the course to include other general level equivalences of the foundation level criteria listed in Table 2.

Changes in the EGRC which may help to improve teaching and learning

The third aim of the study was to identify any changes in the EGRC which might lead to improvements in the teaching of basic competences in mathematics. Although the researchers were working with the EGRC as a basis for the framework, two adaptations were found to be useful. The first was to split the EGRC into even smaller components. It is probably not feasible to

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A range of different competences in mathematics can be included in a single EGRC.

At what level of detail is it reasonable to expect teachers to operate? Should they focus their teaching on those aspects within an EGRC which are likely to cause problems for their pupils?

expect teachers to work at this level of detail but the fact that component parts of single EGRC behave in different ways suggests that care needs to be taken in using the EGRC when planning courses. Two examples will serve to illustrate this point.

One of the EGRC at general level reads 'use the properties of shape to calculate angles, lengths, areas and volumes'. Two of the component parts of that group (calculate the circumference of a circle, solve right angled triangles) are among a small number of criteria which have been identified as discriminating consistently between grade 4 and grade 5 performances. Another of the researchers' criteria (evaluate formulae in symbols) forms one component of an EGRC which includes calculations in number and measure. Again it behaves differently from the rest of the group, consistently discriminating between grade 4 and grade 5 pupils. Focusing decisions on what to teach low attaining pupils only on the basis of the EGRC could, therefore, conceal important aspects of mathematics which are within their competences. This does not suggest a reason for changing EGRC but it underlines the need for teachers to be cautious in the way they are used.

Pupils must be able to progress smoothly from mathematics 5-14 to Standard Grade mathematics.

Are the links between mathematics 5-14 and Standard Grade mathematics clear to all teachers?

Links with mathematics 5–14

The other potentially useful adaptation was to regroup the component parts of the EGRC to highlight the link between the Standard Grade mathematics courses and the 5–14 curriculum guidelines in mathematics. Courses in the first two years of secondary school which are based on mathematics 5–14 must eventually connect with Standard Grade courses and teachers will welcome guidance to help them foster continuity between one system and the other.

Implications for teachers

This study has generated a substantial amount of information about what pupils who attained 'average' or 'low' grades in Standard Grade mathematics actually did. It offers suggestions about what teachers might do to boost the performance of low attaining pupils. An important limitation on the findings however, is that the conclusions have not been tested by acting on the suggestions and measuring the extent to which they do result in greater competence. That may be for future work. In the meantime, if teachers were to build on these findings, what might they do? Four suggestions follow from the statistical analysis of examination scripts and class work while three others emerge from the researchers' experience of conducting the work. Those based on the analysis are as follows:

- Many teachers of pupils who are performing around the borderline between general and foundation level are aware of a barrier between grades 4 and 5 which is difficult to overcome. While it may not be possible to turn all ducks into swans, focusing on those criteria which can be shown to

differentiate highly between the two groups of pupils may help to boost their performance both in terms of their mathematical development and in the examination. The relevant criteria are listed in Table 1.

- Some aspects of foundation level mathematics are tackled satisfactorily by a substantial majority of pupils who have difficulty operating beyond this level (see Table 2). Teachers planning courses for low attaining pupils should ensure that these aspects are covered, not least because of the likely positive effects this might have on motivation.
- Many of the criteria tackled satisfactorily by the lowest attaining pupils have equivalents at general level. These could provide the starting point for teachers looking for opportunities to 'stretch' lower attaining pupils.
- Teachers should be cautious about designing curricula based on the EGRC statements. This study uncovered a number of important differences in pupil competences within criteria.

The suggestions which emerge from the researchers' experience are:

- Most textbooks are poor at identifying those tasks which develop the competences of 'Reasoning and applications'. Teachers should ensure that wherever possible they help pupils to recognise which mathematical competences they are using and so chart individual progression.
- Teachers in the study recognised that it was sometimes difficult to distinguish between giving pupils support and 'spoon feeding' them. Initial training of teachers and indeed inservice staff development might usefully focus on the skills involved.
- Finally, teachers should always bear in mind that the assessment procedures appropriate to obtaining an aggregate score for Standard Grade and those appropriate to supporting teaching and learning can be very different. The claim that Standard Grade examinations are 'criterion-referenced' may be tenuous. Nevertheless, the EGRC can be used to grade a piece of work directly and, hence, to provide a comprehensive profile of pupil competences. Most teachers have this information available from day to day classwork and it would be unfortunate if it were not shared with their pupils.

Further reading

Further details of the research can be found in the full report, ***Standard Grade Mathematics Achievements and Competences 3–6***, which is available from the Scottish Council for Research in Education, 15 St John Street, Edinburgh EH8 8JR, price £7.00.

The views expressed in this paper are those of the authors and do not necessarily reflect those of the Scottish Office Education Department who funded the study.

Notes

Achievements of low attaining pupils

Direct grading to suppport teaching and learning

Competences of borderline pupils

Analysis of mathematics texts

Support for low attaining pupils

Widening the opportunities for low attaining pupils

Focus of teaching

Progress from 5–14 to Standard Grade

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If you have views on ***Interchange*** and/or wish to find out more about RIU's research programme contact the Research and Intelligence Unit (RIU), Scottish Office Education Department, Room 4/48, New St Andrew's House, Edinburgh EH1 3SY.

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